7/PRTS
09/856843
JC18 Rec'd PCT/PTO 25 MAY 2001

Device for Coupling Ultrasonic Waves into a Medium

Technical Field

The present invention relates to a device for coupling ultrasonic waves into a medium via a boundary surface, having at least one ultrasonic transducer unit, which couples the ultrasonic waves into the medium via a coupling medium provided between the ultrasonic-wave-generating unit and the boundary surface.

State of the Art

Devices of the aforementioned type are employed for non-destructive examination of materials and, moreover, find widespread use in medicine for diagnosing inside the human body, for example physical examinations during pregnancy.

The interaction of ultrasound and preferably solid bodies is based, similar to light in glass, on absorption (weakening), reflection and refraction. Reflection and refraction occur at the boundary surface between two substances of different physical properties, e.g. at a boundary surface of a body. As these differences are often small, in particular in the case of composite materials, high sensitivity of the receiver device is a prerequisite by means of which the backreflected ultrasonic waves can be detected. Frequently ultrasound emitters and ultrasound receivers are integrated in one unit and are known as ultrasonic transducer systems. In order to be able to use an ultrasonic transducer both as an emitter and as a receiver, ultrasonic waves are emitted in short intervals and the reflected ultrasound is received in the pauses.

Description of the Invention

The object of the present invention is to improve a device for coupling ultrasonic waves into a medium via a boundary surface, having at least one ultrasonic transducer unit which couples ultrasonic waves into the medium via a coupling

09856843 .052501

medium provided between the ultrasonic-wave- generating unit and the boundary surface in such a manner that the degree of coupling-in, that is the degree with which the ultrasound is coupled into the medium, is distinctly raised. Moreover, the object is also to achieve close coupling between the ultrasonic waves generating unit and the-to-be-examined medium for better detection of the ultrasonic waves reflected at the medium.

The solution to the object forming the basis of the present invention is set forth in claim 1. Advantageous further improvements are described in the subject matter of the subclaims as well as in the specification and in the preferred embodiments.

In air-coupled excitation of the ultrasonic waves, in which the air is utilized as the coupling medium, according to the present invention, a so-called compressed-air sliding shoe, a device which will be described in the following, is employed to decisively improve energy balance.

Air-coupled excitation of ultrasonic waves refers to the ultrasonic transducer unit generating ultrasonic waves in the air, with these ultrasonic waves hitting the boundary surface respectively a solid body surface at a suited angle after passing a more or less long path and excite indirect waves so-called density waves or shear waves or surface waves running along the surface of the solid body, so-called Rayleigh waves or creeping waves, in the medium respectively in a solid body. In this way, various plate-wave modes can be excited even at plate-shaped materials.

The invented device according to the generic part of claim 1, is distinguished by the fact that the ultrasonic waves generated by the ultrasonic transducer unit are directed into a closed volume provided with at least a first opening and a second opening, that a flow of gas, which ensures that there is an overpressure inside the closed volume and simultaneously represents the coupling medium, is directed into the interior of the volume through the first opening, and that the second opening, through which the flow of gas coming from the volume exits, faces the boundary surface directly.

10052501.043950

Preferably compressed air is introduced as the coupling medium into the interior of the closed volume, which is enclosed in a housing. The compressed air flows out through at least one opening on the side of the housing facing the boundary surface. Due to the selective outflow of the compressed air at the underside of the housing of the so-called compressed-air sliding shoe, the sliding shoe is actually sucked to the boundary surface due to the so-called compressed hydrodynamic paradox, thereby yielding very close coupling between the housing and the boundary surface. This again results in a, for the most part, constant distance between the device and the boundary surface thereby improving measuring conditions considerably.

As an alternative to the hydrodynamic paradox effect, the intensity of the gas flow can be raised further in such a manner that a kind of air cushion is formed between the device and the boundary surface so that the entire device hovers over the boundary surface like a kind of hovercraft.

The main advantage of the closed volume, to which compressed-air is applied, inside the compressed-air sliding shoe is that due to the pressure-dependent higher air density inside the housing, the ultrasonic waves can couple more effectively into the medium, which is preferably a solid body, via the boundary surface. Usually the pressure inside the compressed-air sliding shoe is approximately 10 times higher than in the surroundings. Thus, the ultrasonic waves can be coupled into the medium 10 times better.

The purpose of the invented device is coupling in ultrasonic waves preferably at those technical surfaces which, due to cleaning conditions or similar circumstances, cannot be directly contacted with a probe. With the invented device, ultrasonic waves can be coupled in highly effectively via the boundary surface without touching it and without very complicated technology regarding sealing measures connected with maintaining the air pressure inside the housing respectively inside the compressed-air sliding shoe because the pressure conditions set in automatically as a result of the so-called hydrodynamic paradox.

For further details, reference is made to the following preferred embodiments.

Brief Description of the Invention

The present invention is made more apparent in the following using preferred embodiments with reference to the accompanying drawings by way of example without the intention of limiting the scope or spirit of the inventive idea. Depicted is in:

Fig. 1 a cross section of an advantageous embodiment

Fig. 2 a cross section of an advantageous alternative embodiment.

Ways of Carrying Out the Invention, Commercial Applicability

In the simplest form of a preferred embodiment (see figure 1), the compressed air flows into the closed volume 1, which is enclosed by a housing 2. The housing 2 is provided with two openings 3, 4. The compressed air flows into the interior of the housing 2 through opening 3 through a compressed-air line 5 attached thereto. The compressed-air escapes to the outside through the other opening 4. An ultrasonic transducer unit 6, preferably placed on the side facing opening 4, is provided inside the housing 2 in such a manner that the ultrasonic waves can be released directed at the opening 4. In this case, opening 4 also acts as a sound-exit opening.

Preferably, delay-time-controlled stack transducers can be used as ultrasonic transducer units. Conventional transducers can also be built into the compressed-air sliding shoe. In particular for low frequency applications, the individual plates of the stack can be excited in phase. Conventional single oscillator transducers can, of course, also be built in.

The compressed-air flow 9 developing radially between the underside 7 of the housing and the probe surface respectively boundary surfaces 8 generates a vacuum between the two surfaces which draws the compressed-air sliding shoe to the probe

surface 8. The diminishing distance between the underside of the sliding shoe and the probe surface 8 raises flow velocity, which for its part leads to increased contact force. Equilibrium sets in when the force of attraction generated by the radial flow equals the force of repulsion (caused by the pressure building up inside the sliding shoe). The width of the air gap between the underside of the sliding shoe and the probe surface and the amount of pressure inside the sliding shoe depend on the geometric design.

However, the described simplest version of the compressed sliding shoe has certain drawbacks which are caused by gas-flow turbulences inside the housing 2: therefore, in particular, causing the occurrence of disturbing fluctuations in the shape and the amplitude of the ultrasonic pulses inside the housing 2. In order to reduce these disturbances, suited sound-conducting means 10 are built into the interior of the housing 2 in order to deflect the ultrasonic waves accordingly and/or to concentrate, for example on the sound-exit opening 4. The purpose of the sound-conducting means 10 is, in particular, to separate the spatial zone passed by the ultrasonic waves and a spatial zone in which the gas flow introduced into the housing can develop freely. In figure 2, a funnel insert, which concentrates the ultrasonic waves coming from the ultrasonic transducer unit in the direction of the sound-exit opening 4, is provided as the sounding-conducting means 10.

The interaction volume between the turbulent compressed air and sound is therefore very much limited which reduces turbulent effects accordingly. Fundamentally instead of a funnel, all built-in elements such as baffle plates, hole filters etc. can be used which contribute to a laminating or calming the air flow. Of course, any other gas (e.g. CO_2) can be employed instead of compressed air.

Moreover, the sound-exit opening and other compressed-air openings can be disposed on the housing separated from each other.

Depending on the application, the ultrasonic transducer unit 6 can be built into the housing perpendicular to the probe surface 8 or slanted to generate oblique ultrasonic waves. If transmission and reception are realized with two ultrasonic

10525003.0B3550

transducers, they can be built into separate sliding shoes or into a common sliding shoe. In the latter case, the two transducers can have separate sound-exit openings with separate baffles for suppressing turbulences or common sound-exit openings with a common baffle for suppressing turbulences. The geometric arrangement (slanted position, spacing) is adapted depending on the application (testing thick components or thin components, exciting spatial waves, surface waves or plate waves.

List of Reference Numbers

1 closed volume

2 housing

3,4 openings

5 compressed-air line

6 ultrasonic transducer unit

7 underside

8 boundary surface, probe surface

9 compressed-air flow

10 sound-conducting means